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On September 14, 2015 the two detectors of the Laser Interferometer Gravitational-Wave Observatory (LIGO), located in Hanford (Washington) and Livingston (Louisiana) in the United States, observed a transient gravitational-wave signal, called the GW150914. This is the first direct detection of gravitational waves, accomplished a century after the theoretical prediction of Albert Einstein as a consequence of his theory of general relativity. This decisive detection was the result of an international effort that lasted several decades and involved more than one thousand scientists and engineers.

Albert Einstein, only one year after formulating his theory of general relativity, had realised that in the weak-field regime, the linearised field equations admit transverse wave solutions travelling at the speed of light. He called these solutions gravitational waves. Yet the question of their existence as solutions of the fully nonlinear field equations hunted Einstein until the end of his life. The debate on the reality of gravitational waves lasted several decades and was only resolved in January 1957 during the Chapel Hill conference on “The Role of Gravitation in Physics” – known today as the GR1 meeting – during which Felix Pirani proposed a brilliant deduction on how to “measure” gravitational waves. One year earlier, in 1956, Felix Pirani had published an article entitled “On the physical significance of the Riemann tensor”, showing that gravitational waves manifest themselves as fluctuating tidal forces on masses within their path. In this work, Felix Pirani highlights the interpretation of geodesic deviation and its relation to the curvature tensor.

The first gravitational wave detector was developed in the sixties by Joseph Weber, one of the attendees of the Chapel Hill conference. The device he designed and subsequently built, consisted of massive aluminium cylinders – “antennas” – vibrating at a resonance frequency. The principle of these resonance detectors, called “Weber bars”, is based on the effect of gravitational waves on the fundamental resonant mode of aluminium bars at room temperature. By the seventies, there were developed aluminium bar systems operated at and below the temperature of liquid helium, to reduce thermal noise. However, despite several efforts, gravitational waves were not detected.

Hopes were soon raised again with the discovery of the binary pulsar system PSR B1913+16 by Hulse and Taylor in 1974 – recipients of the 1993 Nobel Prize in Physics – and the subsequent observations of its energy loss by Taylor and Weisberg. This discovery provided the first demonstration of the existence – not direct detection – of gravitational waves, leading the hunting for gravitational waves into a new phase.

The most promising design of gravitational wave detectors is laser interferometry offering a way of measuring the motion of widely separated test masses freely suspended as pendulums, produced as they interact with a gravitational wave. In the seventies, Rainer (Rai) Weiss – MIT – conceived the idea of building such a laser interferometer, and by late seventies he experimented with a modest prototype whose two L-shaped “arms” were 1.5 m long. The progress was then rapid. By 1983 Ronald Drever – Caltech – had already built an interferometer whose “arms” measured 40 m. The LIGO project saw the light in the eighties as a Caltech-MIT project funded by NSF; it was originally led by Kip Thorne, Rainer Weiss and Ronald Drever. In 1994 Barry Clark Barish, an experimental physicist – expert in high energy physics with experience in managing large projects – was appointed as the LIGO administrative leader. Barry Barish transformed the Caltech-MIT project into an international collaboration, the LIGO Scientific Collaboration (LSC), that includes today over 1200 people. Barish’s vision was to build the LIGO as an evolutionary laboratory. By the early 2000s, TAMA 300 in Japan, GEO 600 in Germany, LIGO

in the United States, and Virgo in Italy were completed. Combinations of these detectors made joint observations already from 2002.

The initial LIGO, 2002-2010, did not detect any gravitational waves. The upgrade lasted five years and the advanced LIGO (aLIGO) started in February 2015. On the 14th September 2015, four days before the aLIGO starts its official run, the two interferometers detected a burst of gravitational waves from the collision of two giant black holes. In a far galaxy, 1.3 billion years ago, two black holes, of 29 and 36 solar masses, orbiting closer and closer to each other, collided and merged into a single black hole of 62 solar masses, releasing an enormous amount of energy, equivalent of an energy of 3 solar masses times the speed-of-light squared. LIGO had fulfilled its scope and the efforts of Rai Weiss, Kip Thorne and Barry Barish had paid off. The era of Gravitational Astronomy has now begun. Two more detections, the GW151226 and the GW170104, and a lower significance candidate, the LVT151012 have followed. The Advanced Virgo joined the Advanced LIGO twin interferometers on August 1, 2017. Soon afterwards, on August 12, 2017 the Advanced Virgo and the two Advanced LIGO detectors observed gravitational waves from a binary black hole coalescence. This is the first three-detector observation, called GW170814, observed first at the LIGO Livingston and then at the LIGO Hanford and Virgo detectors, with a delay of respectively around 8 ms and 14 ms. Other detectors are planned to join the network: KAGRA is being built in Japan, and LIGO India has been recently approved. European Space Agency has selected the space-based laser interferometer, LISA, for its third large class mission, due for launch in 2034. There are also plans for the third-generation gravitational-wave, such as the Einstein Telescope or the Cosmic Explorer.

On the 3rd October 2017, the Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2017, one half to Rai Weiss and the other half jointly to Barry C. Barish and Kip S. Thorne – all three members of the LIGO/VIRGO Collaboration – *“for decisive contributions to the LIGO detector and the observation of gravitational waves”*. The Nobel Prize acknowledges the efforts of a whole community during 45 years and the decisive contribution, vision and dedication of Barry Barish, Kip Thorne and Rai Weiss.

The years to come gravitational waves are expected to be detected from a variety of sources. Such detections will help us to better understand our universe and test the validity of our theories.